DANIEL H. WAGNER, PRES.
HENRY R. RICHARDSON, SR. V. PRES.
DAVID C. BOSSARD, V. PRES.
LAWRENCE D. STONE, V. PRES.
BARRY BELKIN, V. PRES.
LESLIE K. ARNOLD, SR. ASSOC.
BERNARD J. McCABE, SR. ASSOC.
THOMAS L. CORWIN, SR. ASSOC.
STANLEY J. BENKOSKI, SR. ASSOC.
WILLIAM J. BROWNING, ASSOC.
BRUCE E. SCRANTON, ASSOC.
WILLIAM H. BARKER, ASSOC.
FRANK P. ENGEL, ASSOC.
SCOTT S. BROWN, ASSOC.
ROBERT P. BUEMI, ASSOC.
LARRY K. GRAVES, ASSOC.
JAMES R. WEISINGER, ASSOC.
FRANKLIN B. HERMAN, ASSOC.
JOHN W. PALMER, ASSOC.
MARK E. DAVISON, ASSOC.

DANIEL H. WAGNER, ASSOCIATES
CONSULTANTS
OPERATIONS RESEARCH MATHEMATICS
STATION SQUARE ONE
PAOLI, PENNSYLVANIA 19301

NIAGARA 4-3400
AREA CODE 215

(593)

July ~~28,~~ 1978

MEMORANDUM REPORT

To: Office of Naval Research (LRAPP)
Attn: LCDR K. Evans, Code 6000

Contract No. N00014-75-C-0058

From: D. C. Bossard

Subject: Final Report Under Contract No. N00014-75-C-0058

This is the final report under Contract No. N00014-75-C-0058. The bibliography of work accomplished under this contract is given below in chronological order beginning with the initial proposal dated August 1, 1974, through this final report.

The work accomplished is in five areas:

(1) ASEPS model validation;

(2) ambient noise modeling questions;

(3) second order statistics for ASEPS;

(4) localization and tracking symposium;

(5) Kent Beacon analysis and follow-up exercise planning.

Selection of these task areas was at the direction of LRAPP in response to current needs. In addition to this written analysis, Dr. Bossard participated in a number of discussions and planning sessions with LRAPP personnel.

In the following sections each of the major work areas will be summarized.

1. ASEPS Model Validation

The initial proposal, reference [a], was to devise statistical tests to be used in comparing ASEPS predictions of signal excess with operational data, namely, periods of SOSUS contact with known U. S. SSNs operating along known (or reconstructed) tracks in the SOSUS influence areas, and utilizing calibrated noise projectors. A series of these runs, denotes GNATS I, II, III, etc., were conducted and reconstructed during 1974 and 1975. Most of the data reduction was performed by Mr. Bill Schreiber of Planning Systems, Incorporated, and this phase of our work was done in close cooperation with Mr Dick Klinkner of PSI.

Bibliography entries related to this task area are references [a] (the proposal), [b] through [f], [k], [m], [p], [s] through [v], [y], [aa] through [pp], [rr], and [ss], and span the time from August 1, 1974 to April 1, 1976. The best general summary of the methodology is reference [y], and the results for GNATS I and II is given in reference [cc].

The net result of this work is that a number of useful tests were designed and implemented on a Wang 2200B programmable calculator for use with data as developed in the GNATS reconstruction and the ASEPS output. These tests are designed to show the regions of signal excess statistics (σ, the instantaneous standard deviation and λ the recurrence rate of independent samples) that are compatible with the observed data (SNR at time of detection and the length of contact, as recorded for individual arrays and propagation paths), and to highlight other anomalies that may arise. By reference to independent analyses that estimate the values of λ and σ, it is possible with these tests to infer the compatibility of the operational results to the observed operational data.

In the initial application of the tests, reported in reference [cc], a number of areas were found where model improvements were needed. It is difficult to say whether those areas were revealed by the tests or by common sense scrutiny of the data, but in either event, the need for further ASEPS model development was indicated and so further application of the tests was suspended.

It should be noted that revision of the ASEPS model has recently been completed, and so it is timely to again consider the use of these tests for comparison of ASEPS output with operational data. In general, it should be noted that the utility of the tests developed for this validation will be greatest if the model is free of obvious prediction errors -- when the errors are obvious there is no need for subtle tests.

It should be noted that Wagner, Associates no longer has a Wang 2200B computer and that the principal analyst for this task, Dr. Bill Barker, is on assignment at Naples, Italy. Thus, revival of these test programs would involve some start-up delays.

2. Ambient Noise Modeling

One of the issues in ASEPS is the way in which ambient noise is modeled -- particularly because of interest in directional (horizontal and vertical) structure in the noise. At the start of the proposed work, PSI under the work of Mr. Lou Solomon was engaged in modeling shipping contributions to ambient noise. In late 1974, NUSC, New London, conducted various directional ambient noise measurements in Bermuda. The task, which was briefly studied as part of our work effort, was to devise appropriate statistical quantities (variance, correlation, etc.) that could be used to evaluate the utility of the directional ambient noise modeling in ASEPS.

References [g], [i], [j], [n], [o], [p], [s] suggest simple measures that can be used to compare directional ambient noise data with predictions. These measures were never implemented because the NUSC data has never (to my knowledge) been reconstructed and made available for such analysis. The basic Poisson spatial process (which is quite capable of handling shipping lanes and other known phenomena) as developed in reference [g] remains of value in ambient noise modeling and has been used in other applications of spatial processes.

3. Second Order Statistics for ASEPS

The second proposal, reference [x], extended our analysis into the area of second order statistics for signal excess prediction models. This turn in the work evolved naturally out of the earlier work because of the realization that the utility of ASEPS in the prediction of system performance is closely tied to its ability to predict not only the mean level of signal excess but also the statistical properties of the signal excess about the mean -- to the extent that those properties depend on the environment. It is a fact of life that performance contours for SOSUS are based on assumed second order statistics of the signal excess -- the instantaneous standard deviation of signal excess, σ, and the temporal repetition rate, λ, as much as or more than on the mean level of the signal.

The ASEPS model has a unique potential to correct a universal limitation of all performance prediction schemes, namely that it is assumed that the values of σ and λ are independent of the geographic location and orientation of the arrays, the ambient noise environment, etc. It is well known that these statistical quantities are not universal constants, but until the ASEPS model, there has not been a practical means to predict variations in these parameters.

To give a simple illustration where second order statistics are important, ASEPS can identify those occasions when the propagation path from source to receiver is "nearly" bottom limited -- that situation in which the critical depth is nearly equal to the ocean depth over a significant segment of the path. In such a circumstance, small changes in the propagation path or in the temperature profile may result in large changes in signal excess over the path: this translates into a large value of σ, and perhaps says something about λ as well. It is particularly interesting to note that the repetition rates generally assumed for performance prediction are on the order of one per hour ($\lambda = 1$) to one per three hours ($\lambda = 1/3$). In some localities, this may well be influenced by physically identifiable events -- tides, diurnal temperature shifts, etc.

Once the basic capability of ASEPS to predict mean signal excess is reasonably well established, it is desirable from the viewpoint of operations analysis to go into the second order statistics as implied by the propagation path calculations. This was the thrust of references [l], [r], and [w]. The message of the last of these memoranda is that modifications of ASEPS to produce second order statistics is fairly straightforward and should <u>not</u> substantially increase the computation time*.

The work of these references is preliminary, but clearly shows a useful direction in which to move the would greatly increase the value of ASEPS to the performance prediction community. It is our judgment that profitable further analysis remains in this area.

---

* This assertion has been confirmed in informal discussion with Mr. Chuck Spofford who developed the latest algorithms used in the new ASEPS model.

4. Localization and Tracking Symposium

Reference [z] is a summary report of a special task requested by PME-124 and agreed to by LRAPP in which Dr. David Bossard chaired a panel to review the various localization and tracking algorithms in current use within the SOSUS community. This effort involved two or three gatherings at Bell Laboratories, Whippany, NY, and TRW Systems in McClean, VA, to discuss the models presently in use by Bell Laboratories (the SST and MST algorithms), NOSC San Diego (in the advanced signal processing project) and TRW. The reference summarizes the findings, which basically center around the deplorable situation that prevails in the field in which progress is seriously hampered by lack of scientific interchange due to the claim that the information is proprietary. This is particularly true of various Kalman Filter tracking algorithms. As chairman of the session, I was unable to procure a copy of the Bell Laboratory algorithms for purposes of evaluation and comparison with other approaches to target motion analysis, although the information that could be gleaned was enough to confirm certain opinions as to the nature of the algorithms.

5. Kent Beacon Analysis and Follow-up

As the final task under the contract, Wagner Associates was asked to evaluate the contact data obtained during the Kent Beacon exercise conducted during late 1975. Reference [qq] summarizes that analysis. Based on this work, algorithms were developed which duplicate in principle the detection scheme used on that exercise. These algorithms were developed in reference [tt], [vv], and [ww] for implementation during Church Stroke I. The algorithms and subsequent work on this task were taken over by Dr. John Hanna of Systems Analysis, Incorporated and Bunker Ramo. In our opinion, the algorithms were not properly exercised, so no conclusive information is available for this effort.

David C. Bossard

David C. Bossard

DCB/dd

LRAPP BIBLIOGRAPHY

[a] Proposed Technical Approach, Environmental Prediction Model Tests, Daniel H. Wagner, Associates Proposal to LRAPP, by D.C. Bossard, August 1, 1974, Unclassified (Case 593).

[b] Preliminary Remarks on ASEPS Model Validation, Daniel H. Wagner, Associates Memorandum to LRAPP, by D.C. Bossard, August 9, 1974, Unclassified (Case 593).

[c] Further Remarks on Environmental Model Validation, Daniel H. Wagner, Associates Memorandum to LRAPP, by D.C. Bossard, November 13, 1974, Unclassified (Case 593).

[d] Statistical Tests for ASEPS Model Validation, Daniel H. Wagner, Associates Memorandum to LRAPP, by W.J. Browning, and B.J. McCabe, November 27, 1974, Unclassified (Case 593).

[e] Approximating Sums of (Lambda, Sigma)-Step Processes, Daniel H. Wagner, Associates Memorandum to LRAPP, by B.J. McCabe, December 9, 1974, Unclassified (Case 593).

[f] Remark on CNA Memorandum Concerning Maximum Likelihood Estimation Techniques, Daniel H. Wagner, Associates Memorandum to LRAPP, by D.C. Bossard, December 11, 1974, Unclassified (Case 593).

[g] A Model for Detection by a Field of Correlated Detectors, Daniel H. Wagner, Associates Memorandum to LRAPP, by B.J. McCabe, December 16, 1974, Unclassified (Case 593).

[h] Remarks on ASEPS Model Validation, Daniel H. Wagner, Associates Memorandum to LRAPP, by D.C. Bossard, December 19, 1974, Unclassified (Case 593).

[i] The Effects of Ambient Noise on Correlation in Detection Performance, Daniel H. Wagner, Associates Memorandum to LRAPP, by B.J. McCabe, December 19, 1974, Unclassified (Case 593).

[j] First Passage Problem for the Step Process with a Time-Dependent Jump Rate, Daniel H. Wagner, Associates Memorandum to LRAPP, by B. Belkin, December 20, 1974, Unclassified (Case 593).

[k] Summary of Results to Date, Daniel H. Wagner, Associates Memorandum to LRAPP, by D.C. Bossard, December 20, 1974, Unclassified (Case 593).

[l] Statistics for Sound Velocity Profile, Daniel H. Wagner, Associates Memorandum to LRAPP, by D.C. Bossard, December 20, 1974, Unclassified (Case 593).

[m] Description of the Jump Process Model for Use in Performance Prediction, Daniel H. Wagner, Associates Memorandum to LRAPP, by D.C. Bossard, December 20, 1974, Unclassified (Case 593).

[n] Analysis Proposed for Investigation of Directional and Time-Varying Properties of Ambient Noise, Daniel H. Wagner, Associates Memorandum to LRAPP, by D.C. Bossard, December 20, 1974, Unclassified (Case 593).

[o] A Two-Stage Procedure for Estimating Ambient Noise Distributions, Daniel H. Wagner, Associates Memorandum to LRAPP, by B.J. McCabe, February 14, 1975, Unclassified (Case 593).

[p] Statistical Validation of ASEPS Directional Ambient Noise Predictions (U), Daniel H. Wagner, Associates Memorandum to LRAPP, by D.C. Bossard, and B.J. McCabe, February 19, 1975, Secret (Case 593).

[q] Proposed Environmental Prediction Program in Ambient Noise for FY 1976 and 1977, Daniel H. Wagner, Associates Memorandum to LRAPP, by D.C. Bossard, March 4, 1975, Unclassified (Case 593).

[r] Three Dimensional Piecewise Linear Approximation of the SVP, Daniel H. Wagner, Associates Internal Memorandum to LRAPP, by B.H. Rhodes, April 1, 1975, Unclassified (Case 593).

[s] Statistical Tests for Directional Ambient Noise, Daniel H. Wagner, Associates Internal Memorandum to LRAPP, by W.J. Browning, April 18, 1975, Unclassified (Case 593).

[t] The FANM Spreading Law Versus ASEPS, Daniel H. Wagner, Associates Internal Memorandum to LRAPP, by D.C. Bossard, May 7, 1975, Unclassified (Case 593).

[u] GNATS II ASEPS Prediction (U), Daniel H. Wagner, Associates Memorandum to LRAPP, by D.C. Bossard, May 9, 1975, Secret (Case 593).

[v] Analysis of GNATS II ASEPS Prediction (U), Daniel H. Wagner, Associates Memorandum to LRAPP, by B.J. McCabe, and D.C. Bossard, May 13, 1975, Secret (Case 593).

[w] Incorporation of the SVP Statistics into ASEPS, Daniel H. Wagner, Associates Internal Memorandum to LRAPP, by W.H. Barker, May 15, 1975, Unclassified (Case 593).

[x] Enclosure 1--Technical Approach, Topics in Signal Excess Modelling, Daniel H. Wagner, Associates Proposal to LRAPP, by D.C. Bossard, May 15, 1975, Unclassified (Case 593).

[y] Summary of GNATS Data Base and Testing Capability, Daniel H. Wagner, Associates Proposal to LRAPP, by D.C. Bossard, July 11, 1975, Unclassified (Case 593).

[z] Results of Localization and Tracking Interchange Meeting, Daniel H. Wagner, Associates Proposal to LRAPP, by D.C. Bossard, August 7, 1975, Unclassified (Case 593).

[aa] GNATS I ASEPS Predictions: Reconstruction Data (U), Daniel H. Wagner, Associates Memorandum to LRAPP, by W.H. Barker, October 13, 1975, Secret (Case 593).

[bb] Statistical Data for GNATS I: Supporting Documentation (U), Daniel H. Wagner, Associates Memorandum to LRAPP, by W.H. Barker, October 15, 1975, Secret (Case 593).

[cc] Statistical Summary of GNATS I and Combined GNATS I/GNATS II ASEPS Predictions (U), Daniel H. Wagner, Associates Memorandum to LRAPP, by W.H. Barker, October 21, 1975, Secret (Case 593).

[dd] Obtaining Estimates and Confidence Intervals for the Recognition Differential and Standard Deviation in, Daniel H. Wagner, Associates Internal Memorandum to LRAPP, by W.H. Barker, October 28, 1975, Unclassified (Case 593).

[ee] Plot SNR, Daniel H. Wagner, Associates Internal Memorandum to LRAPP, by S.M. Goodwin, November 1, 1975, Unclassified (Case 593).

[ff] Comments on the Correlation of Fractional Hold Time to Signal-to-Noise Ratio, Daniel H. Wagner, Associates Memorandum to LRAPP, by D.C. Bossard, November 20, 1975, Unclassified (Case 593).

[gg] User's Manual for Computer Program SNRPACK, Daniel H. Wagner, Associates Internal Memorandum to LRAPP, by W.H. Barker, December 11, 1975, Unclassified (Case 593).

[hh] User's Manual for the Program SNR Sort, Daniel H. Wagner, Associates Internal Memorandum to LRAPP, by W.H. Barker, December 11, 1975, Unclassified (Case 593).

[ii] User's Manual for a Computer Program SNROUT, Daniel H. Wagner, Associates Internal Memorandum to LRAPP, by W.H. Barker, December 11, 1975, Unclassified (Case 593).

[jj] User's Manual for Computer Program SUBOUT, Daniel H. Wagner, Associates Internal Memorandum to LRAPP, by W.H. Barker, December 11, 1975, Unclassified (Case 593).

[kk] User's Manual for Computer Program PPRINTSNR, Daniel H. Wagner, Associates Internal Memorandum to LRAPP, by W.H. Barker, December 11, 1975, Unclassified (Case 593).

[ll] Data Structures Used in the SUBPACK and SNRPACK Input Programs, Daniel H. Wagner, Associates Internal Memorandum to LRAPP, by W.H. Barker, December 18, 1975, Unclassified (Case 593).

[mm] User's Manual for the Program FRACHT: Fractional Hold Time, Daniel H. Wagner, Associates Internal Memorandum to LRAPP, by W.H. Barker, December 18, 1975, Unclassified (Case 593).

[nn] Summary of Statistical Tests Used to Validate the ASEPS Model, Daniel H. Wagner, Associates Internal Memorandum to LRAPP, by W.H. Barker, December 23, 1975, Unclassified (Case 593).

[oo] User's Manual for the Program PLOTHISTOGRAM, Daniel H. Wagner, Associates Internal Memorandum to LRAPP, by W.H. Barker, December 24, 1975, Unclassified (Case 593).

[pp] User's Manual for the Computer Program MAXLIKE, Daniel H. Wagner, Associates Internal Memorandum to LRAPP, by W.H. Barker, December 24, 1975, Unclassified (Case 593).

[qq] Review of Kent Beacon Contact Data (U), Daniel H. Wagner, Associates Memorandum to LRAPP, by D.C. Bossard, March 10, 1976, Secret (Case 593).

[rr] The GNATS STATISTICAL PACKAGE, Daniel H. Wagner, Associates Internal Memorandum to LRAPP, by W.H. Barker, March 31, 1976, Unclassified (Case 593).

[ss] Program Status Block: Word 1 and Word 2, Daniel H. Wagner, Associates Internal Memorandum to LRAPP, by W.H. Barker, April 1, 1976, Unclassified (Case 593).

[tt] Design of an Experiment to Address the Kent Beacon Phenomenon, Daniel H. Wagner, Associates Memorandum to LRAPP, by D.C. Bossard, June 7, 1976, Confidential (Case 593).

[uu] Enclosure 1--Proposed Technical Approach-- Further Analysis in Environmental Prediction, Daniel H. Wagner, Associates Proposal to LRAPP, by D.C. Bossard, June 11, 1976, Unclassified (Case 593).

[vv] Frequency Diversity Processing Documentation, Daniel H. Wagner, Associates Report to LRAPP, by D.C. Bossard, and B.M. McDaniel, April 21, 1977, Unclassified (Case 593).

[ww] Changes in the Frequency Diversity Processor, Daniel H. Wagner, Associates Interim Memorandum to LRAPP, by D.C. Bossard, and B.M. McDaniel, May 4, 1977, Unclassified (Case 593).

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
875 NORTH RANDOLPH STREET
SUITE 1425
ARLINGTON VA 22203-1995

IN REPLY REFER TO:

5510/1
Ser 321OA/011/06
31 Jan 06

MEMORANDUM FOR DISTRIBUTION LIST

Subj: DECLASSIFICATION OF LONG RANGE ACOUSTIC PROPAGATION PROJECT (LRAPP) DOCUMENTS

Ref: (a) SECNAVINST 5510.36

Encl: (1) List of DECLASSIFIED LRAPP Documents

1. In accordance with reference (a), a declassification review has been conducted on a number of classified LRAPP documents.

2. The LRAPP documents listed in enclosure (1) have been downgraded to UNCLASSIFIED and have been approved for public release. These documents should be remarked as follows:

   Classification changed to UNCLASSIFIED by authority of the Chief of Naval Operations (N772) letter N772A/6U875630, 20 January 2006.

   DISTRIBUTION STATEMENT A: Approved for Public Release; Distribution is unlimited.

3. Questions may be directed to the undersigned on (703) 696-4619, DSN 426-4619.

BRIAN LINK
By direction

Subj: DECLASSIFICATION OF LONG RANGE ACOUSTIC PROPAGATION PROJECT (LRAPP) DOCUMENTS

DISTRIBUTION LIST:

NAVOCEANO (Code N121LC – Jaime Ratliff)
NRL Washington (Code 5596.3 – Mary Templeman)
PEO LMW Det San Diego (PMS 181)
DTIC-OCQ (Larry Downing)
ARL, U of Texas
Blue Sea Corporation (Dr.Roy Gaul)
ONR 32B (CAPT Paul Stewart)
ONR 321OA (Dr. Ellen Livingston)
APL, U of Washington
APL, Johns Hopkins University
ARL, Penn State University
MPL of Scripps Institution of Oceanography
WHOI
NAVSEA
NAVAIR
NUWC
SAIC

Declassified LRAPP Documents

Report Number	Personal Author	Title	Publication Source (Originator)	Pub. Date	Current Availability	Class.
Unavailable	Bossard, David C.	ACOUSTIC ANALYSIS/ASEPS	Wagner Associates	780726	ADA076268	U
NRLMR3832	Heitmeyer, R., et al.	PRELIMINARY RESULTS OF AN ANALYSIS OF BEAM NOISE IN THE MEDITERRANEAN (U)	Naval Research Laboratory	780901	~~ND~~ ADC016220	U
Unavailable	Watrous, B. A.	PARKA 1 OCEANOGRAPHIC DATA COMPENDIUM	Naval Ocean R&D Activity	781101	ADB115967	U
Unavailable	Dunbar, B., et al.	LAMBDA PROCESSING LABORATORY AND ENGINEERING SUPPORT, FINAL REPORT 1 JANUARY 1977 - 31 OCTOBER 1978	Texas Instruments, Inc.	781129	ND	U
Unavailable	Blumen, L. S., et al.	ASTRAL MODEL. VOLUME 2: SOFTWARE IMPLEMENTATION	Science Applications, Inc.	790101	ADA956122	U
Unavailable	Spofford, C. W.	ASTRAL MODEL. VOLUME 1: TECHNICAL DESCRIPTION	Science Applications, Inc.	790101	ADA956124	U
Unavailable	Townsend, R., et al.	SELF-TENSIONING ACOUSTICAL HORIZONTAL LINE ARRAY (SPRAY) DATA ANALYSIS. FINAL REPORT OF BEARING STAKE TESTS JANUARY THRU MARCH 1977. VOLUME IA. OVERALL PROGRAM PERFORMANCE RESULTS WITH TEST RESULTS SUMMARY	Sanders Associates, Inc.	790101	ADC017573	U
Unavailable	Unavailable	SELF-TENSIONING ACOUSTICAL HORIZONTAL LINE ARRAY (SPRAY) DATA ANALYSIS. FINAL REPORT OF BEARING STAKE TESTS JANUARY THRU MARCH 1977. VOLUME IB. DETAILED DESCRIPTION, TEST RESULTS	Sanders Associates, Inc.	790101	ADC017574	U
Unavailable	Unavailable	SELF-TENSIONING ACOUSTICAL HORIZONTAL LINE ARRAY (SPRAY) DATA ANALYSIS. FINAL REPORT OF BEARING STAKE TESTS JANUARY THRU MARCH 1977. VOLUME II. DATA ANALYSIS FACILITY AND DATA REDUCTION METHODOLOGY	Sanders Associates, Inc.	790109	ADC017575	U
Unavailable	Unavailable	SELF-TENSIONING ACOUSTICAL HORIZONTAL LINE ARRAY (SPRAY) DATA ANALYSIS. FINAL REPORT OF BEARING STAKE TESTS JANUARY THRU MARCH 1977. VOLUME IIIA. DATA POINTS 1, 2 AND 3 RAW DATA	Sanders Associates, Inc.	790109	ADC017576	U
Unavailable	Unavailable	SELF-TENSIONING ACOUSTICAL HORIZONTAL LINE ARRAY (SPRAY) DATA ANALYSIS. FINAL REPORT OF BEARING STAKE TESTS JANUARY THRU MARCH 1977. VOLUME IIIB. DATA POINTS 4, 5 AND 6 RAW DATA	Sanders Associates, Inc.	790109	ADC017577	U
Unavailable	Unavailable	SELF-TENSIONING ACOUSTICAL HORIZONTAL LINE ARRAY (SPRAY) DATA ANALYSIS. FINAL REPORT OF BEARING STAKE TESTS JANUARY THRU MARCH 1977. VOLUME IVA. DATA POINTS 7, 8 AND 9 RAW DATA	Sanders Associates, Inc.	790109	ADC017578	U